**University of Saskatchewan**
**Department of Physics and Engineering Physics**
**E.P. 324.3 Mechanics IV Winter 1996**
**Final Examination April 17, 1996**
**9:00 - 12:00, Physics 127**
**Instructor: Dr. D. Steele**

Time: 3 hours

**Instructions:**
Answer one (1) question from Part 1, two (2) questions from Part 2, and two (2) questions from Part 3.
Calculators and the attached one-page formula sheets may be used. Data you may need are found at the bottom of page 4, and on the following pages.

## Part 1

1. If $KH$ is large enough, the gate will be on the verge of opening when the water level is even with the hinge. What is $K$ for this condition? Neglect the weight of the gate.

2. (a) A barge 20 ft wide and 60 ft long is loaded with rock as shown. Assume that the center of gravity of the rock and barge is located along the centerline at the top surface of the barge. If the rock and the barge weigh 400,000 lbf, will the barge float upright or tip over?

   (b) A cylindrical block of wood 1 m in diameter and 1 m long has a specific weight of 8000 $N/m^2$. Will it float in water with its axis vertical?

**Part 2**

3. Liquid flows through this two-dimensional slot at a rate of $q = 2q_o t / t_o$, where $q$ is the discharge per unit of width of slot and $q_o$ and $t_o$ are reference values. Assume that along the line $y = 0$ the velocity is given by $u = q / b$.
   (a) Write an expression for the local acceleration at the position $x = 2B$ and $y = 0$ in terms of $B$, $t$, $t_o$, and $q_o$.
   (b) Write the corresponding expression for the convective acceleration.
   (c) If $B = 40$ cm, $q_o = 0.2$ m$^2$/s, $t_o = 0.1$ s, and water is flowing, what is the pressure gradient at $x = 2B$ when $t = 0.5$ s?

4. (a) A $u$ component of velocity is given by $u = Axy$, where $A$ is a constant. What is a possible $v$ component? What must the $v$ component be if the flow is irrotational?

   (b) Liquid flows with a free surface around a bend. The liquid is inviscid and incompressible, and the flow is steady and irrotational. The velocity varies with the radius across the flow as $V = 1/r$ m/s, where $r$ is in meters. Find the difference in depth of the liquid from the inside to the outside radius. The inside radius of the bend is 1 m and the outside radius is 2 m.

5. (a) Water is forced out of this cylinder by the piston. If the piston is driven at a speed of 5 ft/s, what will be the speed of efflux of the water from the nozzle if $d = 2$ in. and $D = 4$ in.? Neglecting friction and assuming irrotational flow, determine the force $F$ that will be required to drive the piston. The exit pressure is atmospheric pressure.

   (b) The minimum pressure on a cylinder moving horizontally in water ($T = 10$ºC) at 5 m/s at a depth of 1 m is 90 kPa absolute. At what velocity will cavitation begin? Atmospheric pressure is 100 kPa absolute.

6. (a) A wedge-shaped body with uniform cross-section (as shown in the figure) that is held stable by a wire is free to move in the vertical direction, and has a jet of water striking it from below. The body weighs 50 N. The initial speed of the jet as it comes from the orifice is 15 m/s, and the initial jet diameter is 3 cm. Find the height to which the body will rise and remain stationary. *Note*: The wire is only for stability and should not enter into your calculations.

   (b) A spherical balloon that is to be used in air at 60ºF is tested by towing a 1/3 scale model in a lake. The model is 1 ft in diameter, and a drag of 20 lbf is measured when the model is being towed in deep water at 5 ft/s. What drag can be expected for the prototype in air under dynamically similar conditions? Assume that the water temperature is 60ºF.

**Part 3**

7. Two disks, each of 5-in. radius, are welded to the 18-in. rod *CD*. The rod-and-disks unit rotates at the constant rate $\omega_2 = 3$ rad/s with respect to arm *AB*. Knowing that at the instant shown arm *AB* rotates about the *Y* axis at the constant rate $\omega_1 = 4$ rad/s, determine the velocity and acceleration of point *F*.

8. The telescoping arm *AB* is used to raise a worker to the elevation of electric and telephone wires. Knowing that the length *AB* increases at the constant rate $dl/dt = 0.20$ m/s and that the arm rotates at the constant rate $\omega_1 = 0.25$ rad/s about a vertical axis, while the angle $\theta$ it forms with the horizontal maintains a constant value, determine the acceleration of point *B* when $l = 5$ m.

9. Three 25-lb rotor disks are attached to a shaft which rotates at 720 rpm. Disk *A* is attached eccentrically so that its mass center is 1/4 in. from the axis of rotation, while disks *B* and *C* are attached so that their mass centers coincide with the axis of rotation. Where should 2-lb weights be bolted to disks *B* and *C* to balance the system dynamically?

10. A thin homogeneous disk of mass 800 g and radius 100 mm rotates at a constant rate $\omega_2 = 20$ rad/s with respect to arm *ABC*, which itself rotates at a constant rate $\omega_1 = 10$ rad/s about the *x* axis. For the position shown, determine the dynamic reactions at bearings *D* and *E*.

**Data**

$g = 9.81$ m/s$^2$ = 32.2 ft/s$^2$.

$\mathbf{i} \times \mathbf{j} = \mathbf{k}$ $\quad \mathbf{j} \times \mathbf{k} = \mathbf{i}$ $\quad \mathbf{k} \times \mathbf{i} = \mathbf{j}$
$\mathbf{j} \times \mathbf{i} = -\mathbf{k}$ $\quad \mathbf{k} \times \mathbf{j} = -\mathbf{i}$ $\quad \mathbf{i} \times \mathbf{k} = -\mathbf{j}$